BIOLOGY AND HABITAT REQUIREMENTS OF THE NESTING GOLDEN EAGLE IN SOUTHWESTERN MONTANA

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A Cooperative Study
U. S. Forest Service and Montana State University

February 1975

VITA

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ACKNOWLEDGMENT

I wish to express sincere appreciation to the following people for their contributions to this study: Dr. Robert L. Eng, Montana State University, for technical supervision and guidance in the preparation of this manuscript; James D. Stradley for superb flying and knowledge of the area; Drs. Don C. Quimby and Richard Mackie, Montana State University, for critical review of the manuscript; and to family and friends for their encouragement. The Gallatin National Forest, United States Department of Agriculture, financed this project.

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ABSTRACT

The habitat requirements and biology of the nesting golden eagle *(Aquila chrysaetos)* in the Madison River Basin of southwestern Montana were studied from 1972-1974. Five, seven and ten golden eagle territories were occupied in 1972, 1973 and 1974 respectively, and production averaged 0.91 fledglings per occupied site. A reproductively healthy, if somewhat depressed, population of golden eagles in the Madison Basin seems indicated, though much of the apparent growth in population must be attributed to the author's increased familiarity with the study area. Mean dates of egg laying and hatch were April 2 and May 15 respectively, though great temporal variations in nesting were noted. Fledging of the eaglets occurred between mid-July, and the first week in August. Lagomorphs and sciurids comprised 81 percent of the prey items noted in golden eagle nests. Chi-square comparisons of the distributions of 47 golden eagle cliff nests, and 799 randomly plotted points, indexing cliff site availability, revealed significant ($p<0.05$) to highly significant ($p<0.01$) selection by eagles for sites having: south or east aspect, less than 200 inches average annual snowfall, lower elevation, and greater availability of sagebrush-grassland hunting areas. Mathematical modeling, a stepwise discriminant function based upon these variables, was attempted and limitations of the function are discussed.

INTRODUCTION

Occupying positions near the top of trophic pyramids, populations of golden eagles *(Aquila chrysaetos)* are useful indicators of the stability of the habitat in which they live. The golden eagle has nearly disappeared as a breeding raptor from its range east of the Mississippi River, decreasing significantly in annual migratory bird counts over Hawk Mountain, Pennsylvania (Spofford, 1969, 1971). In the west, the golden eagle appears to be maintaining itself (Wrakestraw, 1972; Heugly *In* Snow, 1973) in spite of locally severe persecution arising from controversial allegations of heavy livestock depredations (Spofford, 1969). Chlorinated hydrocarbon pesticides (DDE, DDT, and dieldrin) have been indicted in the declining reproductive success of the golden eagle in Scotland (Lockie *et al.*, 1969; Ratcliffe, 1970), and suggested as a cause of population decline east of the Mississippi (Spofford, 1971). Possible detrimental conflicts with agricultural land-use have been noted by Kochert (1972) in Idaho.

To minimize land-use impacts on populations of these raptors, their habitat needs must be identified. This study, a cooperative venture between the Gallatin National Forest and Montana State University, centered on the habitat requirements of the golden eagle in the Madison Valley, Montana. Incidental data were collected on bald eagles *(Haliaeetus leucocephalus)* and ospreys *(Pandion haliaetus)* (Appendix B).

Field investigations were conducted on a full time basis from June 12 to September 1, 1972 and from June 11 to September 1, 1973. Aerial surveys were conducted as time and weather permitted during the winter and spring of 1973 and 1974. Production data for 1974 were obtained by a mid-summer aerial survey of occupied nests located during the course of spring flights.

DESCRIPTION OF AREA

Geography and Physiography

The study area included that portion of the Madison River Basin of southwestern Montana lying between Ennis Lake and the boundary of Yellowstone National Park, Wyoming (44°32'N latitude, 111°7'W longitude). The Madison River arises in Yellowstone Park, transects the Madison Range as it flows west and north through Hebgen and Quake Lakes, the Madison Valley, Ennis Lake, the Beartrap Canyon, and the lower Madison Valley. South Meadow Creek, Ennis Lake, and St. Joe Creek formed the northern boundary of the study area, and the Yellowstone Park line a portion of the eastern boundary. Divides of the Madison River drainage formed the remaining boundaries.

The study area is conveniently divided into two sections for the purposes of description, and data analysis. The Hebgen Lake Basin, under jurisdiction of the Hebgen Ranger District of the Gallatin National Forest, extends from the Park boundary to the outlet of Quake Lake. The basin is dominated by Hebgen Lake at 6500 feet, and includes numerous surrounding peaks ranging from 9-10,000 feet in elevation. The Madison Valley, under jurisdiction of the Madison Ranger District of the Beaverhead National Forest, is bisected for most of its length by the Madison River. Elevation varies from 4815 feet (Ennis) to 6195 feet (Quake Lake outlet) along the valley floor. The Madison Range

east of the river includes numerous peaks above 10,000 feet; Hilgaard Peak is the highest at 11,316. The Gravelly Range, west of the river, has numerous ridges above 9,000 feet; Black Butte is the highest at 10,545.

Geology

Precambrian metamorphics (gneiss and related rocks), overlain by strata of Paleozoic, Mesozoic and Cretaceous sediments, were variously and complexly folded, faulted and eroded in the building of the Madison Basin area (Montagne, pers. comm.). Compressional folding and overthrust faulting pushed up the Spanish Peaks and much of the Madison Range over 50 million years ago, while downfolding the Gravelly Range area. More recent tensional faulting dropped the Madison Valley and Hebgen areas to form the present basin. Simultaneous uplifting of the mountain ranges increased elevational differentials.

The Madison River developed upon this system, and alternately eroded or deposited, depending on climatic and geologic influences. The course of the river has been juggled by faulting, and the river has been forced to overtop numerous barriers.

Glaciers have from time to time filled portions of the Hebgen basin, and capped the local mountain ranges. Glaciation and erosion have etched out, in bold relief, cliffs of the more resistant limestones and sandstones, and, locally, cliffs of volcanic intrusives and metamorphics.

Climate

The climate of the Madison Valley is characterized by warm, dry summers, and long cold winters. The average January and July temperatures at Ennis are 21.8 and 64.6 F. respectively. The growing season averages 101 days, and freezing temperatures are noted as late as mid-June, and as early as the first week in September. Annual precipitation averages 10.57 inches at Ennis, with the major peak in precipitation occurring in May and June, and a minor peak in September (U. S. Dept. Com., National Oceanic and Atm. Admin., 1973; Water Resources Division, 1972?).

The Hebgen Basin is cooler and more moist than the Madison Valley. Average January and July temperatures are 10.7 and 59.6 F. respectively at West Yellowstone, and 10.4 and 61.3 at Hebgen Dam. Annual precipitation averages 21.22 inches at West Yellowstone, and 25.84 inches at Hebgen Dam (U. S. Dept. Com., National Oceanic and Atm. Admin., 1972). The average growing season is 62 days at Hebgen Dam (U. S. Dept. Com., Weather Bureau, 1960).

The mountainous areas are much colder, and receive from 30 to 80 inches of precipitation annually; much of it in the form of snow (200 to 400+ inches of snow annually). Snow in the highest elevations often stays until mid-July, and the freeze-free season averages less than 30 days (Caprio, 1965).

Vegetation

Payne (1973) mapped four basic vegetative subtypes for the Madison Basin area. Two forest subtypes, subalpine, and lodgepole pine *(Pinus contorta)*--Douglas fir *(Pseudotsuga menziesii)*, dominate the rough mountainous regions. The foothill sagebrush *(Artemisia* spp.*)* subtype occupies most of the Madison Valley, but is interrupted by extensive areas (not mapped) closely resembling Payne's foothill grassland subtype. These areas are typified by fescues *(Festuca* spp.*)*, wheatgrasses *(Agropyron* spp.*)*, needlegrasses *(Stipa* spp.*)* and wildrye *(Elymus* spp.*)*. For the purposes of this study, foothill sagebrush and foothill grassland are considered together as "sagebrush-grassland". The fourth subtype, intermountain valley grassland and meadow, is limited to the valley bottom near Ennis.

The transition between sagebrush-grassland, and lodgepole pine-Douglas fir forest is not sharply defined in the Madison Basin. The sagebrush-grassland locally tops the Gravelly Range, and extends high into portions of the Madison Range.

Land Use

Ranching is the dominant land use of the Madison Valley. Logging is a major land use in the Hebgen Basin, and is significant in portions of the Madison Valley. Recreation is an important and growing land use throughout the Madison Basin area.

METHODS

Survey

A concerted effort was directed towards locating all eagle and osprey nests (active or inactive) within the study area. Seventy-three hours of aerial survey were complemented by directed search from the ground.

Excellent aerial coverage was provided by repeated, low level (less than 200 feet) flights in a Piper "Super Cub" (PA 18 150). This plane has been noted for its efficiency in locating golden eagle nests (Hickmann, 1972).

Two types of flight patterns were employed in the survey. Extensive flights, directed toward a more general eagle-osprey distributional survey, attempted to cover much or all of the study area in a single flight. These flights followed general preselected contours (e.g. 6500 feet) for golden eagles, and water courses for bald eagles and ospreys. However, deviations from this pattern were frequently made to check areas of reported activity, or sites that appeared promising. Intensive flights, directed primarily toward locating golden eagle nests, consisted of flying "S"-shaped patterns along all cliffs between the valley floor and the divide, with each turn of the "S" placing the pilot and observer two to three hundred feet higher along the same series of cliffs. A tabular summary of the flights is presented in Appendix A, Table 8.

Search from the ground began with query of local ranchers for information on raptor activity, and permission to trespass. Subsequently, many miles of highway, and back-country roads and trails were either driven or hiked, with frequent stops to search cliffs and slopes with a binocular and a spotting scope.

Search from the ground was intensified in areas of reported or observed eagle or osprey activity, and in areas where vagaries of wind or terrain precluded adequate aerial search. Some exceptionally remote areas (notably the Hilgaard high country and upper West Fork) where satisfactory aerial survey failed to locate eagles or nests were not searched from the ground.

Nesting Biology

Golden eagle nests were distinguished from other raptor nests by specific raptor associations, size, construction, and location.

Of the major raptors reported (Skaar, 1969), or observed to nest within the Madison Valley study area, only the bald eagle and osprey build tree nests substantial enough to be confused with golden eagle tree nests (Headstrom, 1951). Osprey nests were distinguished from eagle nests by their characteristic position in the extreme tops of the nest tree (Mathisen, 1968), and remaining eagle nests were separated by the specific associations of bald or golden eagles.

Among other raptors which consistently or occasionally utilize cliff nest sites, falcons either make simple scrapes or acquire sites of other species (Olendorff, 1971), great horned owls *(Bubo virginianus)* almost never build their own nests, and red-tailed hawks *(Buteo jamaicensis)* may either build or acquire (Bent, 1937, 1938). Ravens *(Corvus corax)* may also utilize cliffs as nest sites (Bent, 1946); red-tailed hawk and raven nests tend to be substantially smaller (15-30" vs 30-60+") than golden eagle nests (Headstrom, 1951). However, some unusually large hawk or raven nests may have been mistaken for small golden eagle nests. Error resulting from misidentification of nests is believed to be minimal, involving possibly three which were included with golden eagles.

Nest status was assigned as suggested by Postupalski (1974). A nest was classified as occupied when at least one of the following activity patterns was observed during a given breeding season:

a) young were raised;
b) eggs were laid;
c) one adult observed sitting low in the nest, presumably incubating;
d) two adults present at or near a nest, regardless of whether or not it had been repaired during the season under consideration, provided there is no reason to suspect that this pair had already been counted elsewhere;
e) one adult and one bird in immature plumage at or near a nest, if mating behavior was observed;
f) a recently repaired nest with fresh sticks or boughs on top, and/or droppings or molted feathers on its rim or underneath.

A successful nest was a nest fledging at least one young. Nests were assigned supernumary status only if adults from an occupied site were

observed to use the nest, or green boughs indicated that the nest was being actively maintained. Nests thought to be within an occupied territory, though not showing sign of recent use or repair were assigned the status of possibly supernumary. Inactive nests were those which could not be associated with any breeding pair, and usually showed advanced stages of decay.

Initiation of nesting within the study area was approximated by extensive type aerial survey flights. All active golden eagle nests were visited at seven to ten day intervals during the field season to record the development of the young, activity of the adults, and prey remains observed in the nest or vicinity. Development of the young in 1973 and 1974 was recorded on 35mm Kodachrome or Ektachrome slides. Care was taken to limit the time spent in the immediate vicinity of active nests so as to limit the exposure of the young. Nests were not closely approached as eaglets neared flight stage to avoid forcing premature fledging.

Shortly after the young had fledged in 1973, I rappelled into all five successful nests, and collected prey remains and castings. On June 4, 1974, I rappelled into five of ten active nests, noted prey items and recorded the stage of the young. Prey items collected were identified to genera by comparison to study skins and skeletons in the Montana State University Vertebrate Museum. Most probable species of these prey items were established by reference to Hoffman

and Pattie (1968) and Hoffman *et al.* (1969).

Seasonal nest histories were estimated by back-calculation. The ages of eaglets observed in this study were determined by comparison to pictures and descriptions of known age young (Sumner, 1925). These ages, and the dates of observations, provided the dates of hatch. Egg laying and nest initiation were calculated from incubation and life history data summarized in Bent (1937) and Snow (1973). Calculated nest histories were cross-checked against survey data.

Habitat Requirements

All nests found in 1972 and 1973 were visited at least once, and data on location, aspect, slope, and general cover type associations were recorded. These data suggested that selection for certain environmental factors restricted the distribution of golden eagle nests, and provided a basis for the hypothesis that such factors are sufficiently limiting to provide a useful descriptive model of golden eagle nesting habitat. This hypothesis was tested, in part, by the null: there is no significant difference between the distribution of cliff nests, and the distribution of available cliff nest sites. Discriminant function analysis completed the evaluation of the hypothesis. Test of the hypothesis was limited to the Madison Valley portion of the study area, which contained 51 of the 53 nests located.

Cliffs of the Madison Valley were not randomly distributed, relative to the hypothesized habitat requirements, so an index of availability of "potential" cliff nest sites was obtained by plotting 803 random points on cliffs identified on aerial photos (1:62,500). These points were plotted by positioning a dot grid (1 dot = 10 acres) over cliffs on the photos. The maximum number of points were placed on any cliff or series of cliffs, provided that one point was placed directly over a nest, if present. The following data were taken for all points plotted, referencing the aerial photos, Soil Conservation Service snow survey maps, and topographic maps:

1) site status; nest present, or not
2) aspect; north, east, south or west
3) elevation; to nearest 500 feet
4) average annual snowfall; less than 200", from 200-300", from 300-400", or more than 400"
5) acreage of sagebrush-grassland cover type within 1/4 mile;
    a) total acreage
    b) acreage not obstructed by a ridge exceeding 1,000 feet above the site
    c) acreage below a line defining 200" or more of average annual snowfall
    d) acreage as limited by both b) and c)
6) acreage of sagebrush-grassland within 1/2 mile; a) to d) as in 5)
7) acreage of sagebrush-grassland within 1 mile; a) to d) as in 5)

8) acreage of sagebrush-grassland within 2 miles; a) to d) as in 5)

The distributions of golden eagle nests, and the randomly plotted points representing "potential" sites were compared, relative to the above data, using two-way chi-square tests (Snedecor and Cochran, 1967) and stepwise discriminant function analysis (Dixon, 1973).

Stepwise discriminant function analysis classifies sites by comparing the habitat characteristics of unclassified sites to those of sites already classified, utilizing the variables which describe the characteristics in order of decreasing significance to the function. An "F" of 3.5, approximating a p-value of 0.05 for the degrees of freedom expected was assigned as the level of inclusion or deletion for the variables. The initial groups from which the function was built were established by placing the 47 known cliff nest sites in one group, and 98 sites having no sagebrush-grassland within 2 miles below a line defining 200 inches average annual snowfall into the second, "unused", group. The function was refined by placing initially unclassified sites into the appropriate group, based upon posterior probabilities of 0.995 or greater of belonging to one group or the other. The function was then simplified by using only the statistically and biologically most significant variables, and refined again from the original groups. Data appropriate to the simplified function were taken from an independent sample in the Yellowstone Valley, and the function was tested

against these data.

RESULTS

Nests and Population

Fifty-three nests were located within the study area; twelve were initially located in 1972, thirty-one in 1973, and ten in 1974. Thirty-eight nests were located by aerial survey, and fifteen by search from the ground. Aerial survey proved to be a highly effective tool in locating golden eagle nests, particularly after experience was gained in spotting nests. All nests were eventually observed from the air, and, due to lack of adequate vantage from the ground, aerial survey proved to be the only means by which to check the productivity status of many nests. However, the necessity of complementary search from the ground was amply demonstrated by the difficulty found in the aerial observation of several nests.

Sixteen nest territories were occupied at least once during the three seasons of study (Appendix A, Table 9). Only six (38%) of these territories included nests which could positively be identified as supernumary. If nest sites classified as possibly supernumary are also included, then 9 of 16 (56%) of the territories included supernumary nests. McGahan (1968) reported that 20 of 36 territories (56%) included supernumary nests, Camenzind (1969) 11 of 21 territories (52%), while Kochert (1972) reported that all territories in the Snake River Canyon area included supernumary nests. The utilization of supernumary nests may be an index of site availability. Criteria for

assigning supernumary status are often not mentioned, and the assumption that unutilized nests represent supernumary nests may fail to adequately account for historical nesting distributions.

Six mature pairs, two lone adults, four immatures, and three fledgling golden eagles were identified within the study area in 1972; seven mature pairs, two lone adults, eight immatures, and eight fledglings in 1973; and eleven mature pairs, three lone adults, one immature, and nine fledglings in 1974. These yearly totals represent minimum population estimates, in that they consider as separate individuals only those eagles differentiated by nesting activity, time-space distribution, or field marks (immature). Much of this apparent increase in population is attributed to increasing familiarity with the study area, but some real growth seems indicated by changes in nesting distributions and densities.

Five of the six mature pairs identified in 1972 were believed to have occupied nest territories. The sixth pair frequented a "territory" though no nest could be located. Six mature pairs and one lone adult occupied nests in 1973. One of these nests was a new site located in an area which had been frequented by a single immature bird during the previous season. Three sites had been previously undiscovered. Eleven mature pairs occupied territories in 1974. One pair was seen in the "territory" which had been frequented in 1972, five pairs occupied previously undiscovered nests, and two pairs occupied

sites which had been known inactive in 1973.

Productivity of the Madison Basin golden eagles averaged 1.54 young per successful nest, and 0.91 young per occupied nest (Table 1). The number of young produced per occupied site is recommended by Postupalski (1974) as the most reliable comparison of productivity among major raptor populations. This measure of productivity was 0.84 fledglings per occupied nest in Utah (Camenzind, 1969), 1.32 and 0.95 fledglings in Montana (McGahan, 1968; Reynolds, 1969), 0.97 fledglings in Colorado (Olendorff, 1973), and 1.18 fledglings in Idaho (Kochert, 1972). The comparable productivity of the Madison Basin golden eagles suggests that the population is healthy and reproductively active.

TABLE 1. PRODUCTIVITY OF THE MADISON BASIN GOLDEN EAGLES.

Year	Young Fledged/Occupied Nest
1972	3 / 5 = 0.6
1973	8 / 7 = 1.1
1974	9 /10 = 0.9
Total	20/22 = 0.91

The density of nesting, calculated as the area of a circle having a radius of the average minimum distance between occupied eyries (Kochert, 1972), was one pair per 243 square miles in 1972, one pair per 167 square miles in 1973, and one pair per 92 square miles in 1974. The nesting density found in 1974 approaches the density of one pair per 70.8 square miles found by McGahan (1968), and Reynolds (1969) for

the Yellowstone-Shields River area of Montana, though it is far below the one pair per 28.3 square miles reported by Kochert (1972) for the Snake River, Idaho area.

The distribution of inactive nests relative to occupied territories (Fig. 1) suggests that the population of eagles in the Madison may be depressed from 29 to 57 percent from recent historical levels, depending on the degree of territoriality which is assumed for the eagles. If 28 territories are assumed (a population depressed 57%), the resulting nesting density of one pair per 45 square miles seems unreasonably high for this area. Reynolds (1969) noted that in 1965 the nesting density of eagles in the Shields-Yellowstone area fell to one pair per 105 square miles in response to lowered prey availability. If 17 territories are assumed (a population depressed 29%), a nesting density of one pair per 80 square miles results. However, several of the "potential" territories are on the periphery of the present golden eagle range within the Madison Basin, and may have been established at a time when prey availability and/or territorial behavior encouraged pairs to attempt nesting in more "marginal" areas. These potential territories also include one nest whose identity as an eagle nest may be questionable.

Chronology of Nesting

The initiation of nesting activities by golden eagles in the Madison Basin probably begins in late February or March. The

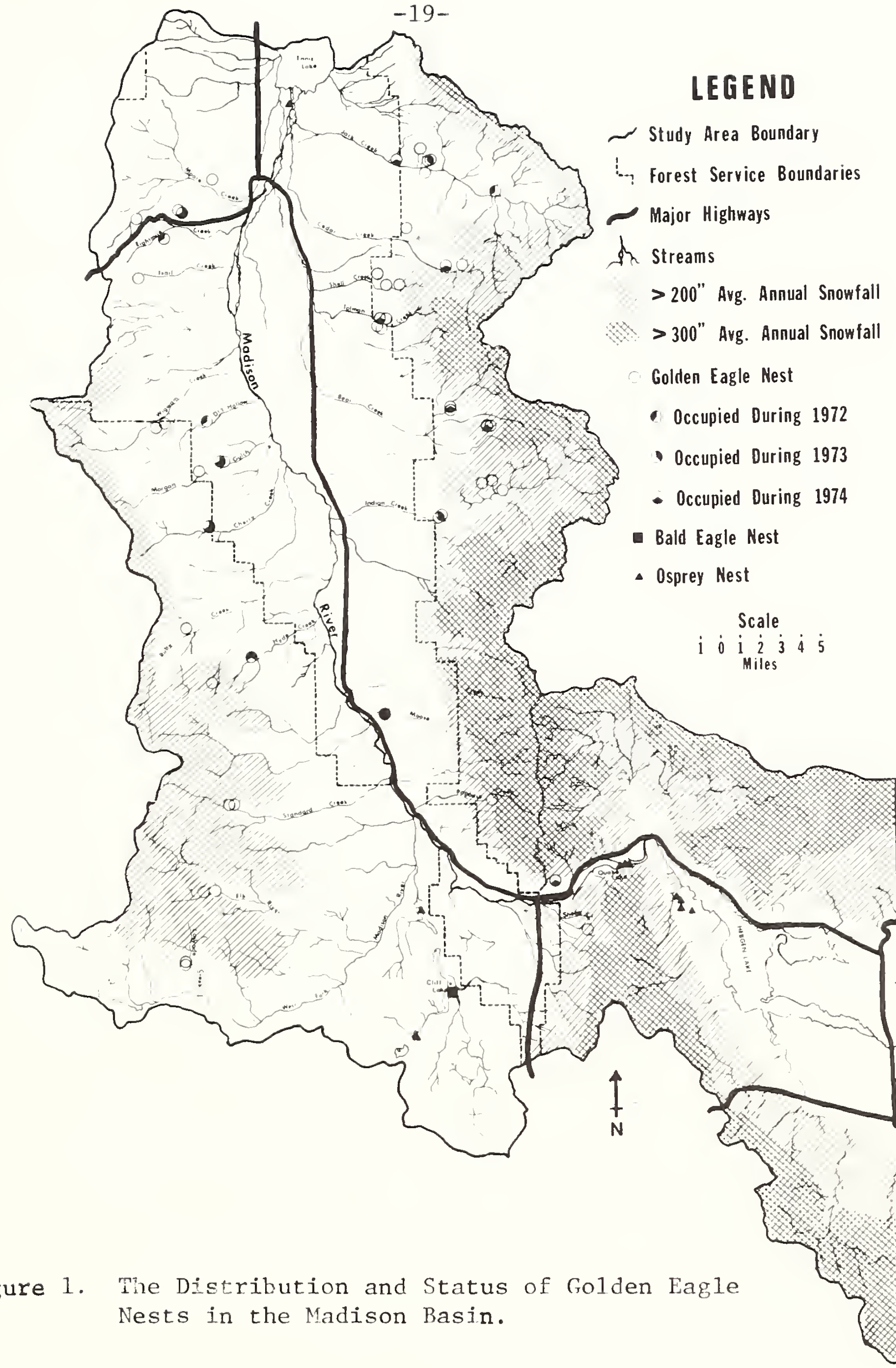

Figure 1. The Distribution and Status of Golden Eagle Nests in the Madison Basin.

calculated dates of initial egg laying range from March 16 to April 11, and the mean date (n=9) was April 2 over the three years of study. Incubation has been observed as early as April 4. Dates of hatch range from April 28 to May 24, with the mean (n=9) date being May 15. The great temporal variation in nesting was demonstrated by four successful nests observed on June 4, 1974. Incubation, possibly of downy young, was observed on one nest, and the young in the three other nests were aged at 2½, 3, and 5½ weeks. Snow (1973) suggests that the time of courtship and nesting varies with altitude, and limited data (n=5) from the Madison area, 1973, tend to support this idea.

The period of incubation for golden eagles of the central and northern Rocky Mountain region has been given as 41 (Reynolds, 1969; Olendorff, 1973) and 42 days (Camenzind, 1969). Incubation periods for two nests in the Madison Valley, where mature birds were observed early in incubation were calculated to be a minimum of 42 and 45 days. A 43 day incubation period was used in the calculation of nest histories.

Fledging of the eaglets occurred between mid-July, and the first week of August, at an age of about ten weeks. After fledging, only an occasional young eagle was seen in the vicinity of its nest, or in the company of the adult pair. A general and fairly rapid dispersal from nesting sites towards the "high country" seems indicated. The

range technician for the Madison Ranger District in 1972 and 1973, reported seeing increasing numbers of eagles (adults and juveniles) on the high summer ranges of the Gravelly Mountains as the summer progressed (Coddou, pers. comm.). Delayed phenology at higher elevations with resulting greater availability of more vulnerable immature prey could provide a valuable food resource for eagles at this time.

Dispersal may be as much a mechanism for winter survival as migration for golden eagles of the Madison area. Eagles are frequently seen along high ridges in the Madison and Gallatin Ranges throughout the winter (Stradley, pers. comm.), and feeding on carrion on high elk winter ranges in Yellowstone National Park (Houston, pers. comm.). Some pairs may winter within their nesting territory. One pair, presumed to be from a nest in the immediate vicinity, is frequently observed scavenging along the Ennis-Virginia City highway for car-killed rabbits and deer (Thompson, pers. comm.). Other eagles have been observed in mixed groups (bald and golden) feeding upon waterfowl wintering along warmer spring-fed streams in the valley.

Food Habits

Staple prey species of the nesting golden eagle in the Madison Basin include white-tailed jackrabbits *(Lepus townsendii)*, mountain cottontails *(Sylvilagus nuttalli)*, yellow-bellied marmots *(Marmota flaviventris)* and ground squirrels *(Spermophilus* sp.*)*. These

lagomorphs and sciurids comprised 81 percent of the 69 prey items identified in this study, and 82 percent of the estimated edible biomass represented by these prey items (Table 2). A similar dependency of eagles on lagomorphs and sciurids has been noted in numerous other American studies, summarized in Table 3. I observed a greater dependency on sciurids than is generally noted for the Rocky Mountain region. This may be an artifact of the small sample size, but I believe it to be a reflection of prey availability. Kochert (1972) recorded both annual and seasonal fluctuations in food habits of golden eagles, in response to prey availability. Reynolds (1969), in a follow-up of McGahans (1966) study noted a significant decrease in the utilization of lagomorphs and a corresponding increase in the utilization of sciurids, a change which he attributed to a depressed rabbit population. Three species of ground squirrels, Uinta *(S. armatus)*, Richardson's *(S. richardsonii)* and Columbian *(S. columbianus)* may occur sympatrically in Madison County (Hoffman *et al.*, 1969). Uinta ground squirrels appeared to predominate, but Richardson's and Columbian were also recorded in an eagle nest on the northwestern edge of the study area.

A fawn deer *(Odocoileus* sp.*)* was the only ungulate represented among the prey items collected. Similarly low frequencies (0.1 to 12.7 percent) of ungulate occurrence in prey samples have been recorded by Kochert (1972), McGahan (1967, 1968), Reynolds (1969),

TABLE 2. PREY ITEMS FOUND IN MADISON BASIN GOLDEN EAGLE NESTS, 1972 to 1974.

Genera	Number of Items (%)	Average Weight[1]	Total Weight	Wastage Factor[2]	Utilized Biomass	(%)
Marmota	11 (16.0)	7.5 lbs.	82.5 lbs.	0.3	57.8	(32.0)
Spermophilus	28 (40.5)	0.8	25.2	0.3	17.6	(9.7)
Lepus	13 (18.8)	7.5	97.5	0.3	68.3	(37.8)
Sylvilagus	4 (5.8)	2.2	8.8	0.3	5.4	(3.0)
Odocoileus	1 (1.4)	30.0	30.0	0.4	18.0	(10.0)
Dendragapus	7 (10.1)	2.0	14.0	0.2	11.2	(6.1)
Perdix	1 (1.4)	0.9	0.9	0.2	0.7	(0.4)
Pica	3 (4.3)	0.4	1.2	0.2	1.0	(0.6)
Corvus	1 (1.4)	1.0	1.0	0.2	0.8	(0.5)
Total	69 (99.7)		261.1		180.8	(100.0)

[1]Burt and Grossenheider, 1964; Mussehl, 1960; Edminster, 1954; Parmalee, 1952.

[2]Brown and Watson, 1964.

TABLE 3. COMPARATIVE DEPENDENCY ON LAGOMORPHS AND SCIURIDS AS A FOOD RESOURCE FOR GOLDEN EAGLES.

Study	Area	Percent Lagomorphs	Percent Sciurids	Sample Size
This study	Montana	24.0	57.0	69*
Murie, 1944	Alaska	10.0	65.0	31*
Murie, 1944	Alaska	0.5	92.0	632**
Carnie, 1954	California	28.6	27.8	503*
McGahan, 1967	Montana	69.8	11.6	980*
Reynolds, 1969	Montana	46.1	22.0	1009*
Whitfield *et al.*, 1969	Saskatchewan	95.0	--	19**
Kochert, 1972	Idaho	72.1	8.2	1302*
Mollhagen *et al.*, 1972	Texas & N. M.	69.2	19.7	946*
Mosher (pers. comm.)	Utah	48.0	21.0	48*

*Remains of prey items

**Castings

Mosher (pers. comm.) and Mollhagen *et al.* (1972). Mule deer *(O. hemionus)* fawns were the most frequently recorded ungulates in these prey samples. Domestic sheep *(Ovis aires)* or goats *(Capra hircus)* comprised from 0.2 to 7.0 percent of the prey samples collected by Reynolds (1969), Mosher (pers. comm.) and Mollhagen *et al.* (1972). While actual kills of ungulates by eagles have been documented (Cameron, 1908; Willard, 1916; Aiken and Warren *In* Bent, 1937; Wood, 1946; Lehti, 1947), much of the ungulate "prey" items recorded in nests was probably taken as carrion. Wiley and Bolen (1971), in a livestock carcass census of west Texas and New Mexico, found that only 25 percent of all deaths among lambs and kids could be attributed to predation. The low frequency of occurrence of ungulates in prey samples at nest sites probably underrates the significance of ungulates as a food source for golden eagles in that it fails to consider the greater edible biomass of the ungulates, and the possibilities of ungulate carrion being consumed where it is found. Lockie, in Scotland, estimates that sheep and red deer *(Cervus elaphus)* carrion comprise about 25 percent by weight of an eagles diet in summer, and 38 percent in winter (Brown and Watson, 1964). Woodgerd (1952) recorded American pronghorn *(Antilocapra americana)* remains in the stomachs of 8 of 51 eagles he examined in Montana.

Blue grouse *(Dendragapus obscuris)* was the most significant avian prey species of the Madison golden eagle. The shape of the primary

feathers found would indicate that the seven gouse identified were immature birds. At least one of the magpies *(Pica pica)* recorded as prey was also obviously immature.

Human-Eagle Interactions

No eagle mortalities attributable to overt human interference were observed during the course of this study. Most ranchers in the Madison Valley expressed little open animosity toward eagles, though several believed that shooting, both by unthinking "sportsmen", and sheepherders engaged in illicit "predator control", continues to be a major cause of eagle mortality in the area.

Two eagles, one bald and one golden, were reported to me as power line mortalities during the study (Schurr, pers. comm.). These occurred in the early spring at power poles along the Madison Valley floor. The valley bottom is used as a wintering, and spring staging area, and power poles may be especially attractive perches at that time. Such artificial perches are little used in mountainous areas where natural perches such as trees or rock outcroppings are readily available (Boeker, 1972). This may partially account for the relatively low incidence and seasonal occurrence of reported eagle electrocutions in this area.

The reaction of nesting golden eagles to human activity varied according to the nature and pattern of the activity. Low flying aircraft proved to be of little disturbance, as incubating eagles rarely

responded to deliberate low passes of the "super cub" which were intended to flush the bird. Several nesting pairs appeared to be habituated to regular activity presented by a highway, ranch, ranch road, or trail, though any departure from the regular pattern of use represented a disturbance. My approach to any one of four successful nests, from one of the above centers of activity, quickly caused the adult birds to abandon their perches until I left the area.

Habitat Requirements

Cliffs were by far the most utilized type of nest site within the Madison Basin study area, forty-nine of the 53 nests (92 percent) being so located. Other studies have shown similarly high utilization of cliff sites by golden eagles. Sixty-two percent of 92 occupied, and unoccupied nests in southcentral Montana (McGahan 1968), and 87 percent of 79 scattered through Wyoming, Colorado and New Mexico were located on cliffs (Wellein and Ray, 1964). Eighty-seven percent of 31 nesting activities in Utah were located on cliffs (Camenzind, 1969).

Three of the four non-cliff nests were located in Douglas fir trees, and the fourth was located in a Ponderosa pine *(Pinus ponderosa)*. McGahan (1968) noted that Douglas fir was the next most commonly used site in southcentral Montana, with 28 percent of 92 nests located in Douglas fir. The nest trees were all large, and the nests averaged 55 feet above the ground. Nest trees were either isolated, or located on

the fringes of small stands of timber, offering commanding views of the surrounding areas and immediate proximity to extensive areas of sagebrush-grassland. Two of the four nest trees were located in the bottom of their respective drainages; slopes in the vicinity of all four exceeded 30-40 percent. While these tree nests showed characteristics of habitat similar to those of "more favorable" cliff nest sites (Appendix A, Table 9), they were deleted from attempts to quantify the habitat requirements of nesting golden eagles because no index of availability could be established for "potential" tree nest sites.

A very positive selection was demonstrated for nest sites having south or east exposures. Sixty-two percent of 47 nests in the Madison Valley were on south aspect cliffs; 17, 13 and 9 percent were on east, west and north aspect cliffs respectively. These figures are very comparable to those found by McGahan (1968) of 50, 23, 18 and 9 percent of 22 nests on south, east, west and north aspect cliffs respectively. However, McGahan states that aspects appeared to be equally available in his area, while this was not the case within the Madison Valley. When the distribution of cliff nests within the Madison Valley is compared to site availability (Table 4), 13.1, 8.0, 2.1 and 1.7 percent of south, east, west and north aspects respectively are utilized. If sites above a line defined by 300 inches or more of average annual snowfall are eliminated, in an attempt to eliminate bias

TABLE 4. THE DISTRIBUTIONS OF NESTS AND SITES WITH RESPECT TO ASPECT.

	North	East	South	West	Chi-square	p-value	d.f.
			All Sites				
Nests	4	8	29	6	29.42	0.0000	3
Sites	234	100	222	243			
Only those sites below 300 inches average annual snowfall							
Nests	4	8	29	6	17.31	0.0009	3
Sites	137	69	159	100			

associated with the inclusion of large numbers of sites which may be unsuitable for reasons other than aspect, then 18.2, 11.6, 6.0 and 2.9 percent of south, east, west and north aspects respectively are utilized. These data suggest a more positive selection for east aspect sites than does the simple comparison which assumes equal site availability.

McGahan (1968) suggests that south and east aspects are favored for the patterns of insolation which they receive. East aspects, in particular, are warmed by the morning sun yet are sheltered from the hot afternoon sun. One occupied nest in my study, at 9200 feet on a northeast face, was subjected to a general air temperature that was 15 F colder (as measured from the aircraft, May 3, 1974) than a nest one and a half miles away, and 2000 feet lower, on a west aspect cliff in the North Fork of Bear Creek. Both nests produced young that season. Early morning sun may have significantly raised the

temperature at the immediate site of the higher nest.

Elevation of occupied and unoccupied nests ranged from 5500 to 9500 feet, with occupied nests ranging from 5800 to 9500 feet. The utilization of potential sites shows an inverse correlation to elevation and differences in distributions of nests and sites were highly significant (X-square = 115.704, p = 0.0000, d.f. = 4). However, the elevational distribution of nests within the Madison Basin study area is approximately 2000 feet higher than that reported by McGahan (1968) for the Shields River-Yellowstone River area (Table 5). This suggests that factors other than simple elevation determine the distribution of golden eagle nesting, though variables which may more directly influence this distribution, such as snow cover and proximity and availability of sagebrush-grassland, are highly correlated to elevation.

TABLE 5. ELEVATIONAL DISTRIBUTIONS OF GOLDEN EAGLE NESTS WITHIN THE MADISON BASIN, AND THE SHIELDS RIVER AREA (McGahan 1968).

Elevation ranges (in 1000 feet)	Number of Nests (percent)	
	Madison Basin	Yellowstone-Shields River
3-4	--------	3 (4)
4-5	--------	37 (46)
5-6	3 (6)	28 (35)
6-7	24 (45)	8 (10)
7-8	12 (23)	4 (5)
8-9	12 (23)	--------
9-10	2 (4)	--------
Totals	47 (101)	80 (100)

Forty-seven of the 53 nests within the Madison Basin were located in areas receiving less than 200 inches of average annual snowfall, and no nests were located in areas receiving more than 300 inches (Fig. 1). A 2 X 2 chi-square test, comparing distributions of the Madison Valley cliff nests and sites, above and below the line defining 200 inches average annual snowfall, showed a highly significant selection for sites below this line (X-square = 90.13, p = 0.0000, 1 d.f.).

Highly significant differences (chi-squares greater than 25, p-values of .0001 or less) in the distributions of nests and sites, relative to the availability of sagebrush-grassland, indicate a positive selection for nest sites more proximal to sagebrush-grassland cover types (Table 6). The differences in distributions become less than significant (p-values greater than 0.11) when considering total sagebrush-grassland availability with 1/2, 1, and 2 mile radii, if sites above a line defining 300 inches average annual snowfall are eliminated. However, the classes of sagebrush-grassland availability subjected to more restrictive criteria of inclusion (i.e. only the acreage below a line defining 200 inches average annual snowfall) maintained significant ($p<0.05$) to highly significant ($p<0.01$) differences. Eliminating such sites in considering the significance of sagebrush-grassland availability may not be justifiable, as availability of sagebrush-grassland and average annual snowfall are inversely correlated, and

TABLE 6. CHI-SQUARE COMPARISONS OF THE DISTRIBUTIONS OF NESTS AND SITES RELATIVE TO THE AVAILABILITY OF SAGEBRUSH-GRASSLAND COVER TYPES.

	All Sites			Those Sites Below 300" Average Annual Snowfall		
Variable	Chi-square	p	d.f.	Chi-square	p	d.f.
1/4 mile						
a)[1]	50.64	0.0000	7	15.23	0.032	7
b)[2]	57.42	0.0000	7	23.17	0.019	7
c)[3]	110.615	0.0000	7	67.86	0.0000	7
d)[4]	110.615	0.0000	7	67.86	0.0000	7
1/2 mile						
a)	25.34	0.0001	4	7.00	0.135	4
b)	37.93	0.0000	4	11.48	0.021	4
c)	73.47	0.0000	4	30.51	0.0000	4
d)	73.47	0.0000	4	30.51	0.0000	4
1 mile						
a)	34.31	0.0001	7	6.79	0.452	7
b)	46.14	0.0000	7	11.60	0.114	7
c)	85.36	0.0000	7	33.03	0.0001	7
d)	85.36	0.0000	7	33.03	0.0001	7
2 miles						
a)	31.50	0.0001	6	9.08	0.168	6
b)	47.52	0.0000	6	14.18	0.027	6
c)	57.59	0.0000	6	19.07	0.004	6
d)	61.79	0.0000	6	21.34	0.002	6

[1]Total acreage of sagebrush-grassland available.

[2]Acreage of sagebrush-grassland not obstructed by a ridge exceeding 1000 feet above the site.

[3]Acreage of sagebrush-grassland below a line defining 200" average annual snowfall.

[4]Acreage of sagebrush-grassland restricted by both b) and c).

the resulting lack of sagebrush-grassland may be a major factor in preventing utilization of these sites.

The significant differences in distributions of cliff nests and "potential" sites, relative to the above hypothesized habitat requirements, provide for the rejection of the null. Aspect, elevation, average annual snowfall and the availability of sagebrush-grassland cover types are accepted as habitat requirements which limit the distribution of golden eagle nesting.

Twenty-two variables (Table 7) were included in the initial stepwise discriminant function. Two "refinements" of the function placed 193 sites in the "nest" category, and 518 sites in the "unused" category. Eighty-eight sites were left "unclassified". Nine sites of the nest category (including 4 actual nests), and seven sites of the unused category were misclassified. Deletion of these sites from their respective categories might have slightly "improved" the classification, but would have altered little the function and relative importance of the variables being considered.

Eight variables were selected for the simplified discriminant function (Table 7). Four were selected because of their high significance to the refined initial function: elevation, average annual snowfall at the site, total acreage of sagebrush-grassland within one mile, and acreage of sagebrush-grassland within two miles below a line defining 200 inches of average annual snowfall. The four aspect variables (north, south, east or west) were selected in spite of their low "F"-values, because of their independence of the other variables, and

TABLE 7. VARIABLES CONSIDERED IN STEPWISE DISCRIMINANT FUNCTION ANALYSIS.

Variable	"F"-Values in the Initial Function to Delete	"F"-Values in the Initial Function to Include	"F"-Values in the Simplified Function to Delete	"F"-Values in the Simplified Function to Include
Aspect				
West		-0.0005		0.0054
South	1.9816		5.225	
East		-0.0015		0.0044
North	3.8670		8.0286	
Average Annual Snowfall at Site	189.3622		92.3610	
Elevation	125.3823		351.1790	
Availability of Sagebrush-Grassland				
Within 1/4 mile				
a) total	6.0680		------	
b) not obstructed	8.9811		------	
c) below 200"[1]	0.8683		------	
d) not obstructed and below 200"	0.8735		------	
Within 1/2 mile				
a)	0.1048		------	
b)	0.1367		------	
c)	15.6592		------	
d)	13.3224		------	
Within 1 mile				
a)	88.9783		360.7808	
b)	0.3642		------	
c)	20.0419		------	
d)	12.8037		------	
Within 2 miles				
a)	19.9054		------	
b)	33.5779		------	
c)	103.2008		177.7027	
d)	98.3440		------	

[1] c and d in all classes had within group correlation coefficients >0.995.

their potential for adding descriptive value to the function. All variables describing sagebrush-grassland availability which included the restriction: "not obstructed by a ridge exceeding 1000 feet above the site" were deleted from consideration at this point. Extremely high correlation coefficients (0.995 or greater) suggested that this restriction added little explanatory power to the function (Table 7). Refining the simplified function established that sagebrush-grassland availability (1 mile - total), elevation, sagebrush-grassland availability (2 miles - below 200") and average annual snowfall at the site were the most important variables. South and north aspect, the most and least favored aspects respectively, were also included in the function, although assigned much lower levels of significance. As refined, the simplified function was based upon 202 sites classified into the nest category (with 4 known nests remaining misclassified), and 505 sites classified into the unused category. Ninety-two sites were left unclassified.

The simplified function was applied to appropriate data collected for 307 sites plotted on aerial photos (1:62,500) of the west side of the Yellowstone River between Allenspur and Gardiner. This area closely resembles the Madison Valley in elevation, snowfall patterns, and cover type associations. The function proved effective in the discrimination of sites most unsuitable for nesting, but was severely limited in its capacity to discriminate between marginally suitable and highly suitable

sites. Two hundred and thirteen sites were classified as nests, and 94 sites as unused. All 17 nests located in 9.5 hours of intensive aerial survey of this area were correctly classified.

DISCUSSION

Complex and subtle interactions of highly correlated quantitatively described variables, and variables not identified or only qualitatively described, contributed to the limited effectiveness of the discriminant function. The high correlations of variables within the discriminant function itself may have masked variables which were more important than those selected. Types of cliffs utilized for nesting, wind, and behavior of the golden eagle were the most important of the variables considered, but not quantified.

Cliffs of loosely "cemented" materials such as breccias, conglomerates or agglomerates simply sluff as they erode, rather than fracture, and thereby fail to provide adequate ledges to support an eagle's nest. The low availability of this type of cliff in the Madison Valley prevented the assumption that the failure to utilize was selection against. However, qualitative observations in the Yellowstone Valley suggest that large areas of these cliffs are selected against because of their propensity for sluffing, and the large quantities of water which may percolate through them as the snowpack melts.

The sagebrush-grassland cover types are the primary habitat for the golden eagle prey species. Jackrabbits and Richardson's ground squirrels utilize these types extensively; Columbian and Uinta ground squirrels, and cottontails tend to utilize the "edges"; and

yellowbellied marmots, the areas of the sagebrush-grassland where rocks adequate to shelter their burrows are available (Hoffman and Pattie, 1968). The "edges" also provide nesting and brooding areas for the blue grouse (Mussehl, 1960), and important wintering and calving grounds for Montana cervids (Johnson, 1950; Peek, 1962; Constan, 1972), a potential source of carrion. Size and morphology of the golden eagle limit this bird to hunting and scavenging these more "open" cover types (Brown and Amadon, 1968).

Simple energetics of flight and the sustenance of young must ultimately determine the distance from sagebrush-grassland hunting areas an eagle may successfully maintain an eyrie, as evidenced by the general selection for sites having greater proximity and availability of sagebrush-grassland cover type. However, wind may be a mitigating influence in determining this distance. Dixon (1937) noted that golden eagles may fly a much longer indirect route in returning to their nest, in order to take advantage of ascending air currents. The Ruppel's griffon *(Gyps ruppellii)* of East Africa may fly more than 60 miles from their nests in scavenging for carrion, utilizing thermal updrafts (Pennycuick, 1973). Pennycuick identifies four major types of "lifting" air: slope or escarpment lift, wave lift (as the air mass "rolls" over the top of a ridge), thermal lift (from uneven heating of the ground), and frontal lift (from the convergence of air masses). While thermal lift is the most important to soaring birds of

East Africa, escarpment lift is probably far more important to the eagles of cool, temperate climes, especially early in the nesting season when snow cover may prevent the formation of "thermals". Conversely, the "rolling" action of air masses passing over a ridge creates very turbulent "down-drafts" which may totally preclude eagles from nesting on the lee side (Stradley, pers. comm.). The prevailing southwest winds of this area could contribute to the selection against north aspect cliffs.

The territorial imperative is not well defined for the golden eagle. Murie (1944) and Brown and Amadon (1968) suggest that home ranges show considerable overlap, while Dixon (1937) and Camenzind (1969) argue that home ranges of adjacent nesting pairs are generally directed away from one another. Overt agonistic behavior, while not common between golden eagles, has been observed (Brown and Watson, 1964). Display flights and meetings without combat are much more common.

Though the density of nesting in Montana does not approach that observed by Kochert (1972) in Idaho, the availability of nest sites does not appear to limit the distribution of eagle nesting within my study area. Nesting density appeared to fluctuate in response to prey availability in the Yellowstone-Shields River area of Montana (Reynolds, 1969), though a number of non-breeding pairs remained in the area. Brown and Watson (1964) found that populations of nesting

golden eagles were maintained at levels well below what site availability or prey availability would support, but conclude that territories regulating nest densities are ultimately established in response to periods of critically low food availability. The higher nest densities observed by Kochert (1972) may be a response to greater historical food availability, or an artifact of calculating density as a circular area when nest site availability is lineally restricted, thereby encouraging more elliptical territories. It appears that some form of territorial behavior, associated with prey availability, prevents the occupation of many otherwise suitable nest sites.

Nest sites which appear quite marginal may be initiated during periods of population highs, as agonistic behavior of established eagles force new pairs into marginal nesting situations. High prey populations may allow occupation of sites farther from sagebrush-grassland cover types as less energy is expended in actually hunting. The use of eyries over many years (Brown and Watson, 1964) suggests a "tradition" of nesting, possibly maintained by the recruitment of a mate by the surviving member of a pair. Such a "tradition" could sustain a marginal site in spite of its minimal contribution to production of the general population.

MANAGEMENT IMPLICATIONS

The discriminant function (Appendix A, Table 10) may become unwieldy in application, and does not include some important, qualitatively assessed variables. The following are recommended as alternative criteria for identifying golden eagle nesting habitat:

a) Approximately 200 inches of average annual snowfall defines the upper limit of nesting habitat within the areas studied. This may be adjusted as local snowpack and phenology dictate.

b) Sites should be within one mile of extensive sagebrush-grassland cover types, excluding that above a line defined by 200 inches of average annual snowfall.

c) While south and east aspects are locally favored, no aspect should be excluded from consideration.

d) Cliffs of the conglomerate-agglomerate type appear to have little potential as nesting habitat and may be excluded.

e) Major downdraft areas (the lee side of ridges directly interrupting prevailing winds) may be excluded.

Aerial survey, concentrated in areas deliniated by the above criteria, is recommended for locating golden eagle nests. Such surveys should be conducted wherever more intensive land use is anticipated.

Many active eyries in the Madison and Yellowstone study areas are located outside the jurisdiction of the Forest Service. Several nests are located at sites so inaccessible as to preclude possibility of unintentional disturbance in developing local timber or recreational resources. The following recommendations are made for areas where potential conflicts exist between the utilization of resources and the

welfare of an eagle eyrie:

a) Roads or other developments should be placed out of site of the eyrie to reduce the risk of disturbance.

b) Irregular activity (i.e. road construction) in the area of an active eyrie should be avoided from the initiation of nesting (about February 15) until the young are about two weeks old (June 15).

Continued public education as to the aesthetics and ecology of the birds of prey is recommended. Locations of eagle nests should not be generally publicized, but educational materials should be distributed to users of the forests, emphasizing the sensitivity of adult eagles to irregular disturbance (i.e. any approach to a nest), and of the young to exposure (particularly heat) and premature fledging.

APPENDIX

APPENDIX A

TABLE 8. SUMMARY OF SURVEY FLIGHTS.

Date	Area Flown	Duration (hrs.)	Type of Flight
	Madison Basin		
1972			
June 14	Madison Valley	4.2	Extensive
June 16	Hebgen Basin	1.7	Extensive
July 10	Madison Valley	3.1	Extensive
July 14	Hebgen Basin & Madison River	2.7	Extensive
July 16	Madison Valley	3.5	Extensive
July 26	Hebgen Basin & Hilgaard Mts.	3.0	Extensive
1973			
February 2	Madison Basin	3.4	Extensive
March 29	Madison Basin	5.2	Extensive
May 6	Madison Basin	4.0	Extensive
May 17	Madison Valley, E. of River	4.0	Intensive
May 18	Madison Valley, W. of River	3.3	Intensive
June 4	Hebgen Basin	4.1	Extensive
June 5	Madison Valley, W. of River	3.8	Intensive
July 3	Madison Valley, W. of River	4.7	Intensive
July 4	Madison Valley, E. of River	3.5	Intensive
July 13	Hebgen Basin & Hidden Lake Chain	2.2	Extensive
1974			
April 4	Madison Basin	3.8	Extensive
May 3	Madison Valley, E. of River	4.6	Intensive
May 4	Madison Valley, W. of River	4.6	Intensive
May 28	Hebgen Basin	4.0	Extensive
	Yellowstone (Paradise) Valley		
May 24	Allenspur to Rock Creek	4.0	Intensive
May 27	Rock Cr. to Park Boundary	3.5	Intensive
May 31	Allenspur to Park Boundary	3.0	Intensive

TABLE 9. STATUS AND HABITAT CHARACTERISTICS OF GOLDEN EAGLE NESTS IN THE MADISON VALLEY - 1972, 1973 AND 1974.

Nest	Location	Status*			Elevation (feet)	Aspect	Average Annual Snowfall (inches)	Sagebrush-grassland (in acres)	
		1972	1973	1974				1 Mile	2 Miles**
1 Moore Cr.	6 6S 1W	--	PS	PS	5500	S	<200	1990	7710
2 S. Moore Cr.	9 6S 2W	I	I	I	6400	Tree	"	1820	7720
3 Eightmile Cr.	11 6S 2W	--	0(2)	0(0)	5800	S	"	1990	7800
4 Eightmile Cr.	11 6S 2W	--	S	S	5900	S	"	1990	7800
5 Eightmile Cr.	15 6S 2W	0(2)	blown down		6300	Tree	"	1900	7700
6 Trail Cr.	28 6S 2W	I	I	I	6400	Tree	"	1850	7890
7 Wigwam Cr.	3 8S 2W	--	I	I	6700	N	"	1010	6350
8 Wigwam Cr.	3 8S 2W	--	--	I	6700	E	"	1100	6520
9 Dry Hollow	1 8S 2W	0(0)	PS	PS	6400	NNE	"	1860	7850
10 Morgan Gulch	18 8S 1W	--	0(0)	0(0)	6300	S	"	1860	7640
11 Morgan Gulch	18 8S 1W	--	S	S	6300	S	"	1860	7600
12 Morgan Gulch	13 8S 1W	I	PS	PS	6600	S	"	1210	6750
13 Cherry Cr.	31 8S 1W	--	0(2)	0(0)	6600	S	"	1330	5720
14 Ruby Cr.	29 9S 2W	--	I	I	7500	S	"	80	50
15 Fossil Ridge	6 10S 1W	--	I?	I?	8500	E	200-300	350	1200
16 Hyde Cr.	33 9S 1W	0(0)	0(1)	I	7500	S	<200	800	2600
17 Standard Cr.	6 11S 1W	--	I	I	8500	S	"	150	150
18 Standard Cr.	6 11S 1W	--	I	I	8500	S	"	130	150
19 Elk River	36 11S 1W	--	I	I	8700	E	"	280	110
20 Hellroaring Cr.	36 11S 2W	--	I	I	8700	S	200-300	300	40
21 Cascade Cr.	14 12S 2W	--	--	I?	8100	N	<200	250	500
22 Cascade Cr.	14 12S 2W	--	--	I	8100	S	"	250	500
23 Jack Cr.	34 5S 1E	--	PS	0(0)	6000	S	"	1350	4700
24 Jack Cr.	26 5S 1E	--	PS	PS	7500	S	"	80	2050
25 Jack Cr.	36 5S 1E	--	0(2)	PS	6700	ESE	"	375	1195
26 Jack Cr.	36 5S 1E	--	S	PS	6700	SSE	"	375	1195
27 Jack Cr.	4 6S 2E	0(0)	PS	PS	6500	S	"	320	720
28 Jack Cr.	4 6S 2E	I	PS	PS	6700	ESE	"	320	720
29 N. of Cedar Cr.	15 6S 1E	--	I	I	6700	W	"	680	5000
30 Cedar Cr.	25 6S 1E	--	I	PS	7200	S	"	190	300
31 Cedar Cr.	25 6S 1E	--	--	0(1)	7700	S	"	140	300
32 N. of Shell Cr.	33 6S 1E	--	I	I	6500	W	"	720	4210
33 Shell Cr.	33 6S 1E	I	I	I	7000	S	"	520	3390
34 Shell Cr.	34 6S 1E	I	I	I	7000	S	"	190	3340
35 Tolman Cr.	9 7S 1E	--	I	PS	6400	S	"	900	4300
36 Tolman Cr.	9 7S 1E	--	I	0(1)	6500	S?	"	1170	4650
37 Tolman Cr.	9 7S 1E	--	I	PS	6400	N	"	1120	4580
38 Tolman Cr.	9 7S 1E	--	I	PS	6300	E	"	1120	4580
39 N. Fk. Bear Cr.	36 7S 1E	--	I	0(2)	7300	W	"	600	2660
40 N. Fk. Bear Cr.	36 7S 1E	--	I	S	7500	W	"	640	2560
41 The Helmut	5 8S 2E	--	I	S	9100	NNE	200-300	220	260
42 The Helmut	5 8S 2E	--	--	0(1)	9200	ENE	200-300	220	260
43 Indian Cr.	36 8S 1E	--	0(1)	I	6700	S	<200	490	2960
44 Indian Cr.	36 8S 1E	--	S	I	6900	S	"	490	2960
45 Indian Cr.	25 8S 1E	--	PS	I	7100	S	"	680	2500
46 Indian Cr.	20 8S 1E	--	PS	I	8600	S	200-300	70	50
47 Indian Cr.	20 8S 1E	--	PS	I	8200	S	200-300	70	50
48 Indian Cr.	20 8S 1E	--	PS	I	7100	W	<200	130	70
49 Moose Cr.	16 11S 1E	0(1)	0(0)	0(2)	6100	Tree	"	1960	7900
50 Papoose Cr.	5 11S 2E	I	I	I	8400	W	"	20	700
51 N. Sheep Cr.	1 12S 3E	--	I	I?	8400	E	200-300	----	----
52 Quake Lake	36 11S 2E	--	--	0(2)	8000	S	<200	400	2960
53 Hebgen Lake	4 12S 4E	--	--	I?	7000	E	"	----	----

*0 = occupied; ( ) = young fledged; S = supernumary; PS = possibly supernumary; I = inactive; ? = questionable nest.

**Below a line defined by 200 inches average annual snowfall.

TABLE 10. THE DISCRIMINANT FUNCTION.[1]

Variable	Coefficient NESTS	Coefficient UNUSED
South Aspect (0 unutilized or 1 utilized)	7.36162	6.04837
North Aspect (0 or 1)	2.79491	4.34120
Avg. Annual Snowfall (in hundreds of inches)	-10.19964	-6.40817
Elevation (in hundreds of feet)	5.37093	6.25613
Acreage Sagebrush-Grassland		
1 mile, total	0.03043	0.04868
2 miles, below 200" avg. annual snowfall	0.00706	0.00316

[1]Variables are multiplied by the appropriate coefficients, and groups (NESTS or UNUSED) are summed independently. The site is assigned to the group having the smaller sum.

APPENDIX B

Bald Eagles

One bald eagle nest was located within the Madison Basin study area. This nest, on Cliff Lake, was reported as having been productive over most years since 1932 (Monta Neely, pers. comm.). Two, two and one eaglets were successfully fledged from this nest in 1972, 1973, and 1974 respectively; a third eaglet, obviously smaller than its mates, apparently failed to survive fledging in 1972.

This nest on Cliff Lake is ideally situated 55 feet above the ground in a 65 foot dead fir snag which stands on a point, 200 feet above the water, between Antelope Prong and the southwest arm. Its position provides commanding views of the main lake and Antelope Prong, while nearby trees provide views of the southwest arm. Trees upslope, and the remaining bulk of the point appear to provide shelter from southwest storms.

Present levels of boating and fishing activity (primarily trolling fishermen) appear to be of no disturbance, and the nest is zealously watched by fishermen from Neely's Landing Resort. As levels of recreational activity increase, horsepower restrictions on boats using Cliff Lake may become desirable. In view of the historical productivity of this site, it is further recommended that no recreational or industrial developments be allowed to encroach upon the southwest

arm, Antelope Prong, or that portion of the main lake visible from the nest site.

Bald eagles winter along the Madison River and utilize Hebgen, Quake and Ennis Lakes as staging areas in the spring.

Osprey

Eleven osprey nests (Table 11) were identified within the study area. Minimum productivity was calculated at 0.95 young per occupied nest for the three seasons, 1972-1974. This is below the production rate of 1.22 to 1.30 calculated by Henny and Wight (1969) as necessary to maintain a population, but quite comparable to the production of 0.98 from an apparently stable population of osprey at Flathead Lake, Montana (MacCarter, 1972).

Two areas of concentration of osprey nesting activity were noted: Moonlight Bay and Quake Lake. Moonlight Bay is an old logging area located about one half mile upslope from Hebgen Lake. Many cull trees were left standing when this area was logged, and some have had their tops blown out, providing excellent nest sites; four were utilized during this study. The trees killed with the flooding of Quake Lake would appear to provide excellent nesting habitat, and three nests were located in the lake "narrows" off Beaver Creek. Adaption and implementation of the Lassen Forest osprey "Habitat Management Plan" (Kahl, 1971) is recommended for these areas.

TABLE 11. STATUS AND LOCATION OF OSPREY NESTS IN THE MADISON BASIN, 1972 to 1974.

		Status[1]		
Nest	Location	1972	1973	1974
Madison River	15 13S 5E	0(0)	0(2)	0 (blown down)
Moonlight Bay				
1)	36 11S 3E	0(2)	0(3)	0(2)
2)	36 11S 3E	0(1)	0(2)	0(1)
3)	36 11S 3E	I	0(0)	I
4)	1 12S 3E	---	0(2)	0 (unknown)
Quake Lake				
1)	28 11S 2E	0(0)	0(0)	blown down
2)	28 11S 2E	0(0)	I	blown down
3)	29 11S 2E	I	blown down	
Goose Lake	3 16N 41E	0(0)	0(1)	0(0) blown down
Wade Lake	2 12S 1E	0(0)	blown down	
Ennis Lake	11 1S 5S	0(2)	0(1)	0 (unknown)

[1]0 = occupied, I = inactive, ( ) = number of young fledged.

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